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# FULL SCALE DETERMINATION OF THE LIFT AND DRAG OF A SEAPLANE.

By Max M. Munk,
National Advisory Committee for Aeronautics.

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Summary.

The speed, barometric pressure, and number of revolutions of the engine of a seaplane were measured, including tests with stopped engine. The mean data obtained are given in the following note; the results of the gliding tests are used for the computation of the lift and drag coefficients, and by making use of them the results of the engine flights are used for the computation of the propeller efficiency.

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The free flight tests described in this note were made by the author and Dr. Erich Hueckel at the testing station at Warnemuende during the summer of 1918, and are here published for the first time. It was intended to develop a simple method for the examination of the aerodynamical properties of a seaplane independent of the characteristics of its propeller. The instruments had to be simple and self-recording, and no long preparation of the airplane for the test could be allowed. On the contrary, the instruments had to be mounted in the airplane only a short time before

the beginning of the test. The method was used with one airplane only, and the opportunity was taken to determine its lift and drag coefficients and the propeller efficiency.

The seaplane used for these tests was a German Brandenburg sea-biplane with the following characteristics:

Spans 36'-9" and 34'-5½"

Entire wing area, S, 380 sq. ft.

Entire weight, W, 3,200 lbs.

Two floats, two pairs of struts.

Propeller diameter, D, 9' 2¼"

The instruments used for the tests were a chronograph and an ordinary barograph. The first instrument was similar to a Morse telegraph receiver; a paper strip about 1¼" broad, moved with a velocity of about 7" per minute under four needles, which when under the influence of four independent electromagnets, marked the paper without stopping its course. The needles were controlled respectively by an ordinary clockwork, by the flexible shaft of the revolution counter of the engine, by an anemometer of the Robinson type and by hand. The clock gave electrical contacts at intervals of 12 seconds, the shaft leading to the revolution counter always after 26 revolutions of the shaft, corresponding to 52 revolutions of the engine. The anemometer gave contact after each 180 feet of travel of the airplane approximately. The fourth needle was operated manually by the observer when the altimeter had reached certain points. It was intended to operate the fourth needle

automatically too at later tests, making it indicate the density of air. Readings were also made of a thermometer, but the greatest part of these could not be used, for it appeared subsequently that the thermometer was too near to the exhaust. The density therefore had to be calculated. This was done by means of the formula $\rho = 1/8 \cdot .9^h$ kg sec² m⁻⁴ where $h$ denotes the altitude in kilometers as indicated by the altimeter.

Gliding tests.- The pilot controlled the airplane so that the dynamic pressure as indicated by the pitot tube was nearly constant. The velocity decreases then during the dive and the negative acceleration of the airplane is to be taken into account in the computation of the final results. The path is slightly curved too, but the centrifugal force is neglected in this paper. Let $w$ denote the vertical velocity and $V$ the total velocity, and let the angle $\epsilon$ be defined by the relation $\sin \epsilon = w/V$. The slope of the path then is taken into consideration if the usual formula for the power is replaced by the following formula

$$\frac{C_D}{C_L^{3/2}} = - \frac{w}{\cos^{3/2} \epsilon} \sqrt{\frac{S}{W} \frac{\rho}{2}}$$

which for small angle $\epsilon$ assumes its ordinary form.

$C_L$ is calculated from the formula $W = C_L \, q \, S$ and, on substitution in the preceding formula, $C_D$ is deduced.

All instruments were carefully gauged before each test; the weight of the airplane was deduced for each test by taking into account the weights of the pilots and the estimated consumption of

fuel. The table at the end of the note gives the mean values obtained from each series of tests.

Tests with running engine.- The horsepower of the engine was assumed to be

$$N = \frac{n}{n_o} \; \frac{\rho - .015}{.125 - .015} \; N_o$$

where $N_o$ is the power delivered at the normal number of revolutions $n_o$ and at the density of the air 0.125 kg sec²/m⁴, and $\rho$ is the density of the air in the same units.

The mean results are contained in the table. The efficiency of the propeller was deduced by making use of the drag coefficients obtained by the gliding tests; the drag of the propeller for the stationary airplane determined by a model test, being subtracted.

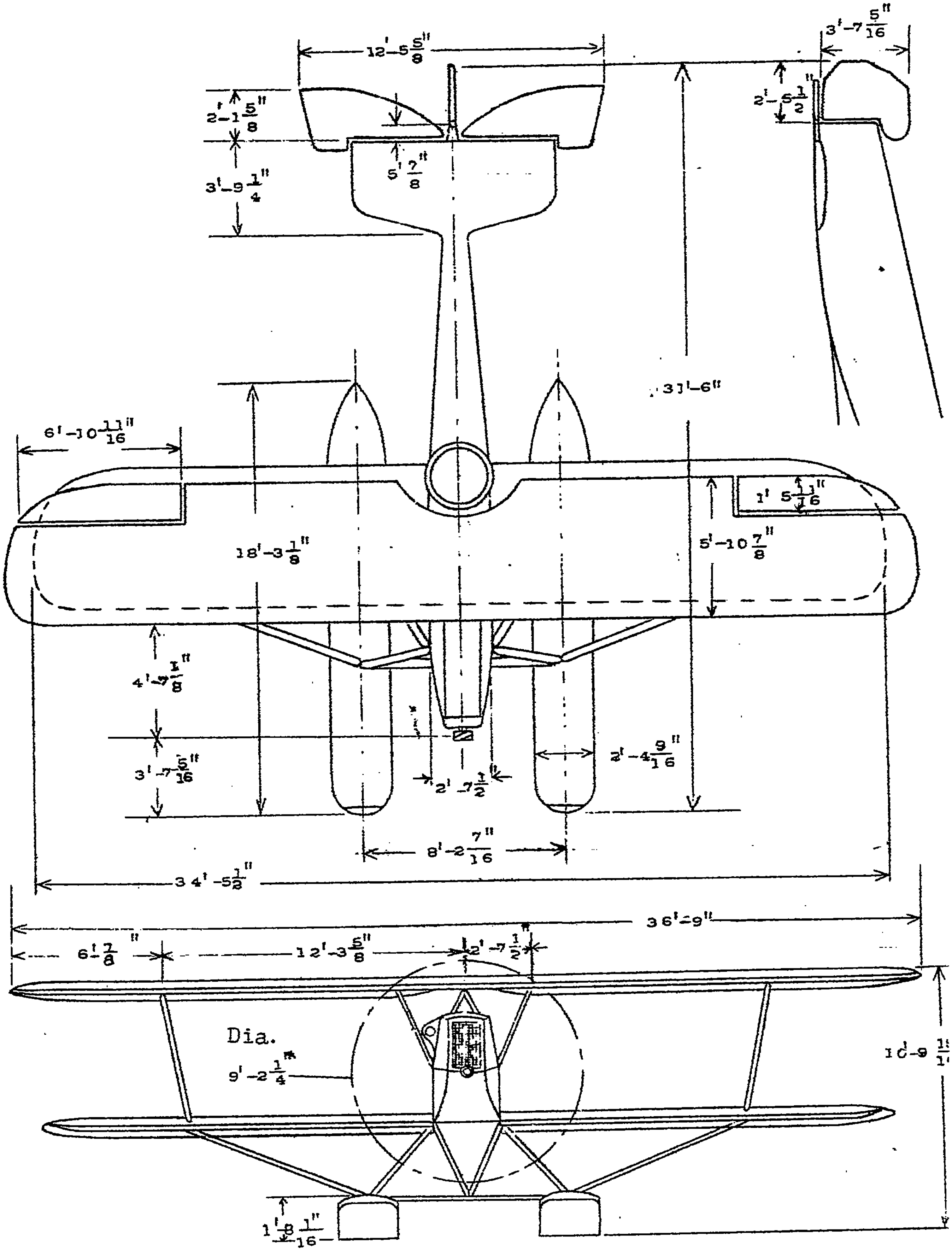
The efficiency thus obtained includes the loss involved by the mutual influence of propeller and airplane, consisting of an increase of the drag, which in general is not wholly neutralized by the increase of the propeller thrust. That is, the efficiency is

$$\frac{C_D \; S \; q \quad V + u \; W}{\text{Brake horsepower}}$$

where $u$ denotes the vertical component of the velocity. This absolute efficiency is different in general from the original efficiency of the isolated propeller.

T a b l e.

| | Gliding tests | | | | | | Engine running. | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Velocity mi/hr | 73 | 80 | 101 | 66 | 72 | 69 | 69 | 83 | 72 | 67 |
| Vertical velocity ft/sec | -16.1 | -21.8 | -35.6 | -13.4 | -16.0 | -15.6 | 2.2 | 0 | -4.3 | 2.5 |
| Dynamical pressure lbs/sq.ft | 12.1 | 15.2 | 24.2 | 9.5 | 12.3 | 11.8 | 10.6 | 15.0 | 11.5 | 9.8 |
| $C_L$ | .67 | .51 | .32 | .81 | .65 | .68 | .79 | .51 | .68 | .90 |
| $C_D$ | .10 | .10 | .09 | .11 | .10 | .11 | .095 | .082 | .090 | .10 |
| $C_D$ propeller drag subtracted | .085 | .085 | .075 | .095 | .085 | .095 | | | | |
| Propeller efficiency % | | | | | | | 63 | 71 | 68 | 55 |
| V/nD | | | | | | | .48 | .54 | .48 | .45 |




Brandenburg Seaplane.